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Clinical examination of the foot and the ankle. Data collection and interpretation of the pathogenic causal sequence of disorders

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KEYWORDS

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Dorsiflexion of the
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Pronation and
supination of the
foot;
Physical examination;
Intra-articular local
anaesthetic test

Summary The clinical examination remains the irreplaceable stage in assessing foot and the ankle disorders. It comprises a complete inventory of the patient's complaints and the data obtained from the physical examination. Afterwards, it should concentrate on establishing consistency between symptoms that can be disparate, to link them in a logical pathogenic causal pattern to be used in developing a treatment programme. These correlations are the most often obvious and only require confirmation with standard X-rays. In the absence of consistency, and if a diagnosis is difficult to establish, recourse to more sophisticated investigations (CT scan, MRI or an intra-articular local anaesthetic test) becomes worthwhile. To achieve maximum value, the physical examination must be based on prerequisite knowledge of functional anatomy, admittedly basic but covering all the bone and joint, ligament, muscle, skin and neurovascular components. All these structures being closely interrelated. This organization allows for remarkable protection mechanisms and the capacity to endure considerable cyclic stress. This interdependence can also command chains of injury difficult to unravel. The examination must thus be methodical and comprehensive: history taking (ranking of symptoms, evaluation of the patient's psychological profile); physical examination, standing, on a podoscope, gait analysis, lying down (trophic disorders, joint range of motion, muscle testing); standard X-rays, always weight bearing. This discursive organization, essential in everyday practice, avoids the sequence "symptom → MRI → surgical indication" which is a professional and intellectual deviance; it enables the development, in terms of advantages against risks, or an appropriate treatment plan in the best conditions.

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Introduction

Foot disorders have two particular features:

- anatomical: the foot is a complex structure of bones, joints and muscles with a perfectly appropriate skin covering;
- semiological: the paucity of clinical signs that come down to pain.

This contradiction and their insufficient knowledge explain the usual helplessness of neophytes when approach-

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ing these disorders. Functional complexity and the uniformity of symptoms explain why further investigations are unsuccessful when used as first line procedures and isolated from any clinical context. The physical examination, in all its aspects, underlies treatment management. Carried out with precision and method, it must arrive at the construction of simple and logical pathophysiological sequences linking apparently disparate data to a common cause, perfectly identified and used as the basis for developing the treatment plan.

Summary of functional anatomy

The foot is the interface between the lower limb and the ground; it withstands static and dynamic stresses that generate considerable compression and shearing forces. Protection is provided by its special architectural organization.

The bones

The anteroposterior arches

The plantar aspect of the heel, the anterior transverse arch and the connecting anteroposterior arches are the main weight bearing structures. The arches form composite beams made of quadrilateral bones assembled by congruent joints and sturdy ligaments, particularly developed at the plantar aspect. One of them, the plantar calcaneonavicular ligament ("spring ligament") plays a major role. Covered with cartilage, it provides passive support for the head of the talus between the sustentaculum tali and the navicula (Fig. 1). This ligament is protected by the tibialis posterior (TP) muscle. In the closed chain pattern, TP contraction, resting on the navicula, opposes plantar tilt. Functioning like an active hammock, the TP provides dynamic protection for the "spring ligament" (Fig. 1). This active-passive protective mechanism depends on deep sensitivity and the proprioceptive reflex path. The fibromuscular structures underlying the arches like a functional frame binder function identically by the combined action of the fibroaponeurotic structures and the intrinsic plantar

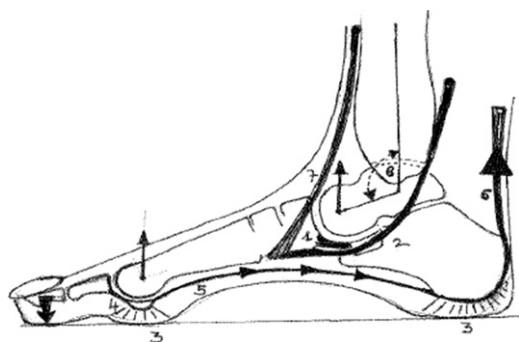


Figure 1 Active-passive mechanisms protecting foot architecture. 1–2: "spring ligament" and tibialis posterior tendon; 3–4–5: metatarsal head fat pads, sesamoid apparatus and flexor hallucis brevis muscle; 4–5–6: triceps surae–calcaneus–hallucis brevis complex; 7: tibialis anterior; 8: sagittal tibiotalar angle.

muscles (triceps surae–calcaneus–hallucis brevis complex) (Fig. 1).

The anterior transverse arch

It permits simultaneous weight bearing on the five metatarsal heads. In lateral view, they are in the same horizontal plane. In the dorsoplantar plane, the presence of the anatomical transverse arch imposes to preserve homogeneous weight bearing a parabolic alignment. In the ideal foot (Maestro criteria), the first and second metatarsals are equal in length while the lateral metatarsals decrease regularly medially to laterally with a length differential that increases following a geometric progression with a common ratio of 2.

The soft tissues

The weight bearing zones

The weight bearing zones of the heel and metatarsal heads are protected by the viscoelastic function of the plantar fat pads, composed of fibrous septa and spaces filled with fat cells (Fig. 1). Several elements optimize this mechanism:

- the thickness of the epidermis and the keratotic layer whose flexibility and reactivity are maintained by sweat glands providing hydration and lubrication;
- the rich vascular network and neurovascular organization. Superficial sensitivity, through the free intraepidermal nerve endings and rapid adaptation corpuscles – the warning system for acute insults. Deep sensitivity, through the mechanoreceptors in the nerve endings of the large myelinated fibers providing protection against chronic microtrauma at the dermoepidermal junction. It maintains cohesion between the various skin layers that are subjected to shearing forces;
- the anchoring on bone structures which opposes the shearing forces, without the possibility of skin-bone rubbing at the heel;
- the metatarsal head fat pads depend on the position of the proximal phalanx (P1) because they are anchored to the sesamoid apparatus (hallux) or the glenoidal fibrocartilage of the lateral metatarsophalangeal joints (lateral rays). Dorsiflexion of P1 causes their forward translation. This provides protection for the extremity of the head, at the heel-off, when bearing weight on the toes "pointe position" (Fig. 2A). But, when P1 is abnormally fixed in extension (claw toe deformity) the head is uncovered and no longer protected in plantar weight bearing (Fig. 2B).

The joints

Definitions

Dorsiflexion (DF) and plantar flexion (PF) are in the sagittal plane. Contrary to flexion, extension of the foot is only situated in the talocalcaneal joint.

In the frontal plane, varus (VR) and valgus (VL) define frontal displacement of the subtalar portion of the heel.

Pronation and supination (P/S) involve the forefoot, the anterior tarsal joint and the tarsometatarsal junction. They are measured by performing a rotating movement around

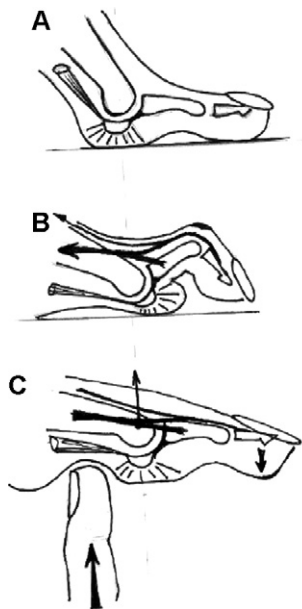


Figure 2 Fixity of the metatarsal head fat pad on the sesamoid apparatus. A. In weight bearing on the point, extension of P1 protects the distal extremity of the head (too-on). B. Permanent DF of P1 (claw toe deformity) causes forward translation of the pad and dorsal interosseous subluxation. C. In simple claw toe, passive horizontalization of M1 restores interosseous action time.

O position with one hand on the heads of the metatarsals, while blocking the heel with the other hand in functional position. O position being defined as the orthogonal position of the transverse arch in relation to the heel. Supination (S) which raises the first metatarsal (M1) is a horizontalization of M1; pronation (P) which lowers it is a verticalization of M1 (Fig. 3A).

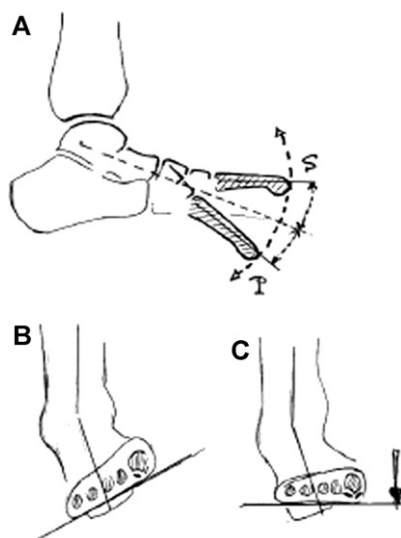


Figure 3 Pronation and supination. A. Definition. B. Homologous mobilization of the hindfoot and forefoot. C. Dissociated mobilization of the hindfoot and the forefoot to preserve homogeneous transverse arch weight bearing.

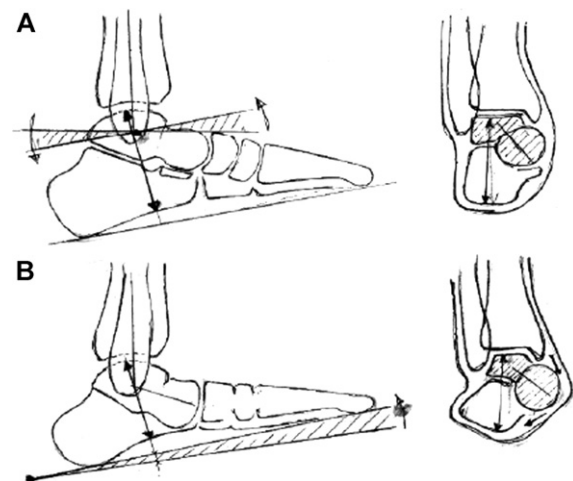


Figure 4 Ankle dorsiflexion. A. Physiological talocrural joint range of motion (1st class lever). B. Subtalar hyperdorsiflexion (2nd class lever) due to reduction in talocalcaneal height and increase in talocalcaneal divergence and heel valgus.

Abduction (ABD) and adduction (ADD) concern displacement of the forefoot in the horizontal plane.

Ankle dorsiflexion

Ankle dorsiflexion (DF) requires specific analysis. Physiologically, in the talocrural joint, the plant approaches the tibia as a first class lever; the fulcrum being the trochlea of the talus. The closure of the tibioplantar angle is accompanied by a spreading of the same amplitude of the tibiotalar angle behind (Fig. 4A). Beyond this physiological range of motion, a few additional degrees of DF are possible. Closure of the tibioplantar angle then takes place like the "leaves of a book" around a posterior hinge (insertion of the Achilles tendon) as a second class lever (Fig. 4B). This is made possible by reduction in height of the talocalcaneal joint through an increase in talocalcaneal divergence and valgus of the heel (Fig. 5A and B). Thus, in the case of a moderately short Achilles tendon, a few additional degrees of DF are still possible, knee extended, when the heel places itself spontaneously in valgus. Passive reduction of this valgus cancels the DF or exteriorizes in flexion (equinus) (Fig. 6A and B).

In summary:

- evaluation of DF should not only be performed with the knee in extension and flexion (to relax the gastrocnemius muscles), but also with the heel free and blocked in anatomical position;
- this capacity for "hyperdorsiflexion" is situated in the subtalar joint and is similar to joint overload;
- measuring the sagittal tibiotalar angle on X-rays permits evaluation of the exact position of the talus in weight bearing. It is defined on a lateral weight bearing view as the angle between the longitudinal axis of the tibia and the axis of the talus. This angle is normally 105° (Fig. 1). A larger angle corresponds to talar equinus, and to the conditions of subtalar overload.

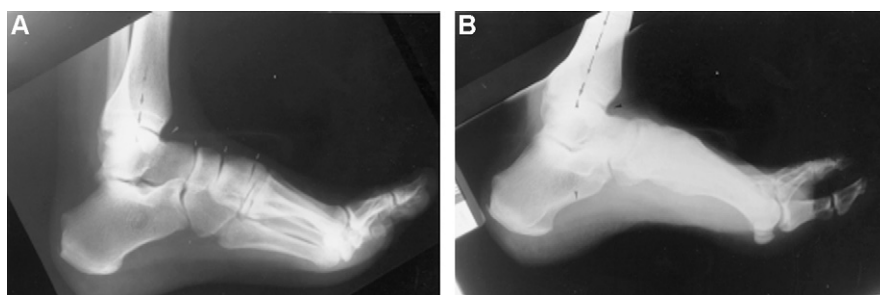


Figure 5 Ankle dorsiflexion – X-ray example. A. Normal DF (note the relationships between the anterior extremity of the trochlea of the talus and the anterior margin of the tibia). B. Hyperdorsiflexion, note the increased range of motion of around 10° without participation of the mid or forefoot joints as well as reduction in the height of the talocalcaneal joint and increase in sagittal talocalcaneal divergence.

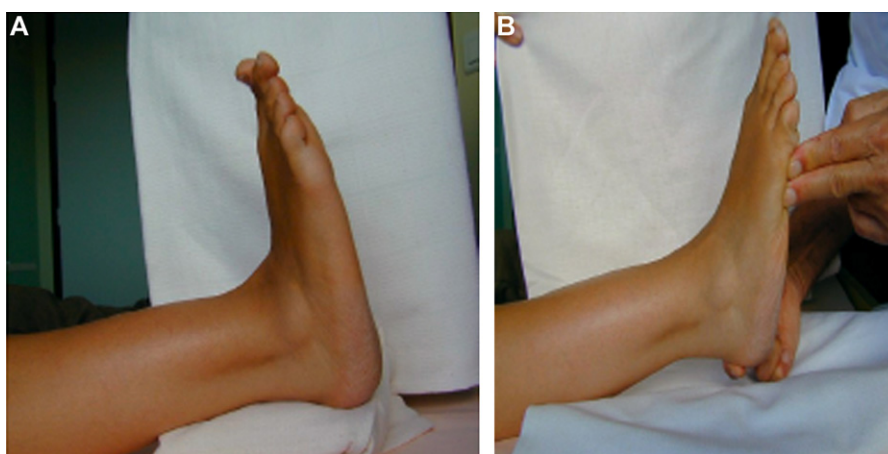


Figure 6 Short Achilles (calcaneal) tendon (clinical presentation). A. Presence of a few degrees of DF, knee extended, when the heel left free places itself in valgus. B. The same manoeuvre, after reduction of valgus, exteriorized an equinus of around 10° .

General architecture – relation between hindfoot and forefoot

In balanced weight bearing

In balanced weight bearing, the plantar aspect is perpendicular to the longitudinal axis of the leg in all planes. In the frontal plane, the heel is in slight (5°) valgus while the anterior transverse arch is perpendicular to the latter. When the foot moves as a block, the varus of the hindfoot is accompanied by supination of the forefoot, and the valgus by pronation (Fig. 3B).

Pronation and supination enable maintenance of anterior transverse arch balance on the ground

Pronation and supination enable maintenance of anterior transverse arch balance on the ground despite heel displacement. In the case of hindfoot varus, active pronation of M1 restores anteromedial weight bearing (Fig. 3C). Likewise, in the case of heel valgus, supination of M1 avoids overload under the first head. It is thus essential to measure separately range of motion in the hindfoot and the forefoot to evaluate the intrinsic freedom of these two sectors and the reciprocal possibilities of adaptation.

Architectural defects

Architectural defects, defined as deterioration in these possibilities of adaptation, cause localized overloads with reactional hyperkeratosis. A distinction must be made between:

- direct hyperkeratosis situated immediately facing a zone of excess pressure;
- indirect hyperkeratosis, secondary to an abnormal antalgic position, caused by excess pressure situated at a distance. Excess pressure under the first head can cause paradoxal hyperkeratosis under the fifth head through antalgic supination.

Locomotion

Extrinsic muscles

The tibialis anterior (TA) is medial and inserts at the plantar surface of the first cuneiform bone and is supinator (Fig. 1). It is only a dorsal flexor of the foot when its action is balanced by eversion (extensor digitorum longus and peroneus brevis muscles).

The posterior tendons (TP and fibular) act as propulsors by pushing on the malleoli in the closed chain pattern.

The flexor digitorum longus and flexor hallucis longus tendons are extensors of the metatarsophalangeal (MP) and flexors of the interphalangeal (IP) joints.

Intrinsic muscles

The flexor hallucis brevis (FHB) and flexor digitorum brevis (FDB) muscles stabilize the MP joints. They are plantar flexors of P1 and extensors of the IP joints (intrinsic + position). The main agents for active impulsion of the pulp, they protect the metatarsal head fat pads (in particular FHB and anteromedial pressure) (Fig. 1).

Gait cycle

The points to be remembered are:

- initiation of the impulsion, which corresponds to advancing the tibia while the plantar surface of the foot is still weight bearing, requires talocrural joint DF of 10° (Fig. 7A);
- the active lifting of the heel and the impulsion overload of the subtalar joint, through action of the plantar flexors, is a closed chain pattern;
- loss of DF and mainly equinus, which cancels the initial impulsion, pushing the heel off and extending the subtalar overload time. They shorten the half-stride length (Fig. 7B and C);
- at the swing phase, action of the TA, combined with that of the everters (indicated by active extension of the toes) stops passive fall of the foot ("steppage" to be differentiated from the "active equinus" in hypertonia of the plantar flexors).

Performing the physical examination

Methodical and comprehensive, the findings must be recorded in writing.

History taking

The quality of patient/physician relations depends on history taking. Precise and directive, without influencing the patient, it should establish a hierarchy of complaints, assess global discomfort, and evaluate the psychological profile. It focuses on analysis of pain, adaptation to footwear, and walking capability.

Analysis of skin projections of the pain permits identification of a joint space. In the case of joint pain:

- the talocrural joint causes an anterior hemicircumferential pain along a horizontal line situated 1 cm above the point of the medial malleolus and at 2.5 cm from the same lateral landmark;
- the subtalar joint causes a submalleolar pain, lateral and/or medial (then indicative) and very characteristic talalgia;
- the midtarsal joint causes pain on the dorsal aspect of the foot, at the base of the tibial crest. Localized involvement (talonavicular or calcaneocuboid) radiates in a half

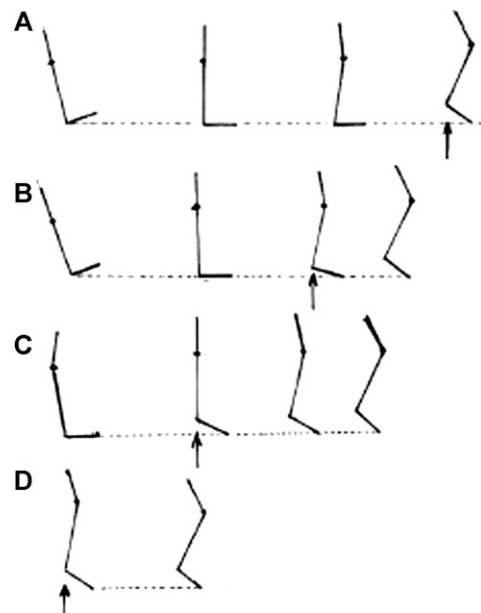


Figure 7 The various phases of locomotion with weight bearing. A. Physiological sequence requiring around 10° of talocrural DF (initiation of the impulsion). B, C. Loss of DF and plantar flexion (equinus) advances heel off (arrow) time and extends the time of subtalar overload. D. metatarsal equinus permanently overloads the subtalar joint.

arch towards the plantar surface. The calcaneocuboid joint space is situated one centimeter behind the styloid process of the fifth metatarsal (easily identifiable);

- the tarsometatarsal joint space also causes pain on the dorsal aspect, at mid-distance between the MP and mid-tarsal joints;
- the second MP (second ray syndrome) causes sharp pain on the dorsal aspect with characteristic ascending radiation.

Podoscope examination

After a sufficient period of adaptation, it enables:

- analysis of the footprint and its four sectors: heel, lateral weight bearing band, anterior transverse arch, and pulp of the toes;
- examination of global foot morphology: frontal orientation of the heel (posterior view) – morphology of the arches and toe position (lateral view) – morphology of the forefoot and alignment of the medial ray (dorsoplantar view).

Gait analysis

This stage has two requirements: sufficient dimensions of the consultation premises and good clinical experience of the physician.

Weight bearing phase

The heel strike phase is evaluated on position and contact of the heel. Prolonged contact with excessive talus pressure indicates delayed heel rise (like in the pes calcaneus gait)

and weakness of plantar flexors. Its disappearance suggests equinus. Avoidance can correspond to talalgia.

Plantar weight bearing must be complete, balanced and sufficient in duration. In the case of major equinus, it can be partial with complete offloading of the heel (and compensating flexion of the knee) in metatarsal equinus (Fig. 7D). It can be preserved in plantar equinus which corresponds to a moderate deformity and is accompanied by compensating recurvatum of the knee (Fig. 7C).

Initiation of impulsion is a very important phase to evaluate. Its disappearance indicates the loss of talocrural dorsiflexion.

The impulsion associates active elevation of the heel, frank weight bearing on the anterior transverse arch, and active pressure on the pulp (intrinsic + position). Avoidance or disappearance of this phase can correspond to either metatarsal pain, or subtalar pain. This phase disappears with paralysis of the plantar flexors.

Of note, the hopping gait due to hollow feet is caused by a reduction in anterior weight bearing phase (metatarsal pain) and the heavy gait due to flat feet corresponds to avoidance of the impulsion (subtalar and/or midtarsal pain).

Swing phase

The position of the foot and the protrusion of the tendons on the anterior aspect of the instep and the dorsum of the foot should be detailed.

Single leg stance on the toes-Single Heel Rise (SLST)

SHR explores two sectors:

- strength of the triceps surae. A score of 5 indicates symmetrical SHR on the healthy side (stability of weight bearing and amplitude);
- continuity of the TP tendon. Normally, SHR is performed with the heel in varus. In posterior view, the lateral edge of the foot is not apparent. In the case of TP tendon rupture, the heel and foot have a strong lateral slant; the lateral edge of the foot and the lateral toes become very visible in posterior view. This is the "too many toes sign" that indicates decompensation of valgus flat foot.

Examination patient lying down

All the following items must be explored.

Skin condition and trophicity

- Identification of impingements (collateral ligaments, dorsal surface [midfoot, toes]).
- Examination of the plantar aspect:
 - skin covering: localization and description of possible hyperkeratosis lesions (calluses, corns, callosity) or ulcerations (relationships with adjacent bone and joint structures).
 - study of sensitivity:
 - superficial sensitivity: (touch, prick) referring to the anatomical territories (dorsum of the foot: superficial peroneal nerve; dorsal surface of the first interdigital commissure: deep peroneal nerve; lat-

eral edge of the foot: sural nerve; plantar aspect: tibial nerve),

- deep sensitivity: hallux position sense, vibratory sensitivity (tuning fork).
- Distal pulses. Further examinations are only justified if they are not palpated.
- Trophic condition (sweating, local coloration and warmth), condition of the nails.

Eliciting the pain

- Palpation of the insertion and the paths of the fascia, muscles and tendons.
- Palpation of the bony structures (collateral ligaments, dorsal surface, heel bones).
- Applying stress to the joints (combined axial compression and rotational stress).
- Exploration of nerve paths (grooves, search for Tinel's sign).

Measure of joint range of motion

It must be bilateral and complete:

- talocrural: dorsiflexion-knee extended-knee flexed (DF/KE/KF). Dorsiflexion-heel blocked (DF/HB/KE/KF) plantarflexion (PF);
- subtalar: by quartiles; one being normal range of motion referring to the healthy side. In the case of stiffness, the position (in active zone or in abnormal position) of the residual sector or of the heel must be indicated (in the case of complete ankylosis);
- intrinsic pronation and supination of the forefoot;
- MP and IP. We include MP stability (second MP) by applying sagittal stress to P1 ("Lachman phalangeal" sign).

Reducibility of deformities

This is a major criterion for treatment:

- in morphological disorders of longitudinal arches: reducibility of the deformities permits treatment with conservative techniques or arthrodesis by simple avivement (arthrodesis in situ), contrary to irreducible deformities that require joint resection with bone cuts (tarsectomies);
- for claw toe deformities: We assess the potential for reduction with horizontalization of the shaft obtained with direct pressure on the metatarsal necks using the radial edge of both index fingers. Disappearance of the claw toe indicates reduction of the dorsal subluxation of the interosseous and lumbrical tendons in the metatarsophalangeal sector (Fig. 2C). It indicates efficacy of an orthopedic innersole with a support behind the metatarsal heads. Irreducibility of the deformity contraindicates this orthosis, considering the risk of worsening the dorsal impingement with the shoe by increasing thickness of the foot.

Muscle testing

This involves all the groups. Testing the intrinsic plantar flexors (FDB and FHB) is particularly important. It uses the synergy uniting the extrinsic plantar flexors of the ankle (TP, Fibular, Triceps surae) and intrinsic flexors of the toes

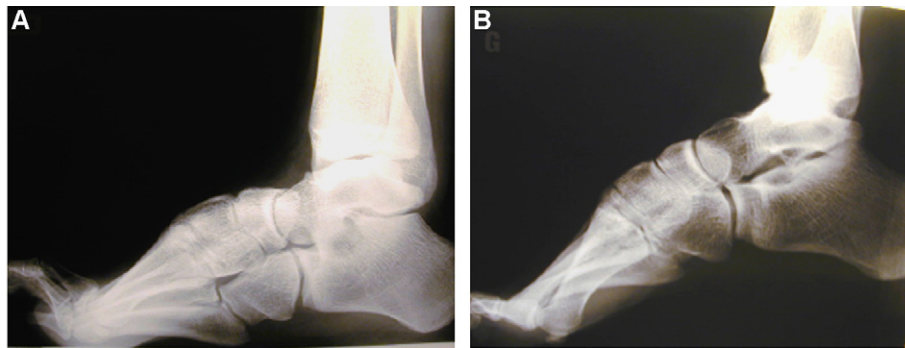


Figure 8 X-rays, lateral view, weight bearing (medial hollow foot). A. Hyperpronation of MI is reduced by hindfoot varus. B. Realignment of the heel exteriorizes the excessive verticalization of MI.

by bringing into play the triceps surae—calcaneus—hallucis brevis complex (Fig. 1). The manoeuvre is performed in two stages. The patient must first perform complete active plantar flexion of the ankle (to initiate the synergistic chain and exclude the extrinsic toe flexors). Then, while maintaining this position, the patient performs active flexion of the toes against resistance by the examiner on the pulps. Using the intrinsic muscles causes MP flexion and IP extension (intrinsic + position) and the possibility of direct palpation of plantar muscle contraction. In the case of paralysis of the intrinsic muscles, a claw is formed (or persists if it was already present).

In the case of posterior presenting signs

In the case of posterior presenting signs, examination in supine position is indispensable to examine the Achilles tendon and its insertion. In this position, when the knee is in extension, the foot free at the end of the table, spontaneously places itself in plantar flexion of around 20°. This defines "physiological equinus". This sign, and triggering of passive plantar flexion of the foot by direct compression of the calf (Campbell—Thomson manoeuvre) guarantee Achilles tendon integrity.

Global examination of lower limb

Examination finishes with evaluation of lower limb alignment and proximal joint range of motion, and a more extensive examination if required by the context.

Examination of the footwear

This stage completes the examination. The usual type of shoe is noted, and above all the types of footwear that cannot be worn. Possible deformities must be detected (asymmetrical wear of the heel and/or the outer sole, wear of the point, stained appearance of the inner sole).

Summary of major points. relationship between complaints and objective data

In the case of agreement

In the case of agreement between the functional signs and the examination data, the diagnosis does not raise any problems. Confirmation with a standard X-ray is sufficient. Four

films should be taken in weight bearing, with magnification 1: both ankles in frontal view (with wire skin cerclage of the heel—Meary view), dorsoplantar frontal view of both feet, and a strict profile for each foot. Unless there has been a recent injury, the X-rays must be in weight bearing; this is the only way to evaluate an architectural defect or the status of a joint space. The presence of a marked varus deformity can make interpretation difficult. When the plate and the bony skeleton are not parallel for the lateral view, there is a risk of underestimation of the medial ankle architectural defects (Fig. 8A and B).

In the case of non-agreement

In the case of non-agreement between history taking and physical examination, more sophisticated imaging studies are indispensable. It should be noted that CT scans and CT arthro-scan are the most appropriate for bone and joint structures, and MRI for soft tissues.

Interlinked symptoms, likely to involve adjoining joints can oblige recourse to an intra-articular local anaesthetic test.

The technical performance must be rigorous; collaboration with an experienced radiologist is indispensable. Check arthrography is necessary to verify that the injection is intra-articular and selective. If there is leakage of the anaesthetic agent into an adjacent joint cavity because of the anatomical communication or technical error, the test does not have any value. The imaging study must be completed with a sufficiently prolonged standard clinical test. The findings of this test must be noted in detail in the examination report.

In the presence of obvious osteoarthritis of the ankle, it is sometimes difficult to decide on the real status of the subtalar joint. The changes on the imaging studies are not necessarily symptomatic (and vice versa). This is where the test comes into the forefront and should include the following stages:

- intra-articular injection by posterolateral approach in the subtalar joint of a mixture of lignocaine and contrast medium;
- radiographic check of the selectivity of the injection and possible performance of CT arthro-scan (depending on the duration of the anaesthesia);
- clinical test: walking outside, using stairs, running (VAS score);

- if necessary, counter-test with anaesthesia of the talocrural joint to clarify the direct responsibility of this joint space.

Pathogenic causal sequences

The final summary must include all the data from the examination in a simple and logical pathogenic pattern. Though practically always obvious, finding the link can sometimes turn out to be more difficult. For example, valgus flat foot does not usually require any treatment because it is well tolerated. This deformity can however, through talar malposition in valgus-equinus, cause a series of successive deteriorations with medial plantar impingement, tenosynovitis and rupture of the TP tendon, followed by talonavicular dislocation, then talocrural dislocation in valgus resulting in stress fracture of the fibula. Identification of the original cause and the pattern of development is essential; the isolated treatment of a symptom removed from its context is doomed to immediate failure.

Diagnostic traps

Lesions with similar clinical presentations can cause confusion:

- chronic post-traumatic laxity of the ankle and fibular tenosynovitis in the context of medial hollow foot through various instability. Also in this context, instability due to an architectural defect can be mistaken for post-traumatic laxity;
- osteoarthritis of the ankle and subtalar decompensation. Obvious osteoarthritis of the ankle, but perfectly well tolerated, can be the origin of painful decompensation in the subtalar joint through talar equinus;
- subtalar or talonavicular osteoarthritis and TP tendon damage in the context of valgus flat foot; these two lesions present with medial submalleolar pain;
- morton's neuroma and second ray syndrome can be wrongly identified following an examination that was rapid and incomplete;
- and many other causes.

Conclusion

The clinical examination remains the key stage in the management of disorders of the foot and the ankle. It avoids the sequence "symptom → IRM → surgical indication". This approach, seen far too often in daily practice, overloads radiologists, burdens the budget of the social security system, and is the source of serious errors. When

exact agreement between the patient's complaints and the objective data is found, or in the case of non-agreement, after further more sophisticated examinations, the clinical examination permits construction of a simple and logical pathogenic causal sequence; this sequence is the basis for developing a treatment plan according to the relationship between advantages/risks and the patient's profile.

Conflict of interests

None.

Because of sole learning aim and statement of basic concepts, bibliographic references are not mentioned in text (instead succinct reference works are done).

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